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EVALUATION OF A 30-MM THIN WALL STEEL CARTRIDGE CASE.(U)

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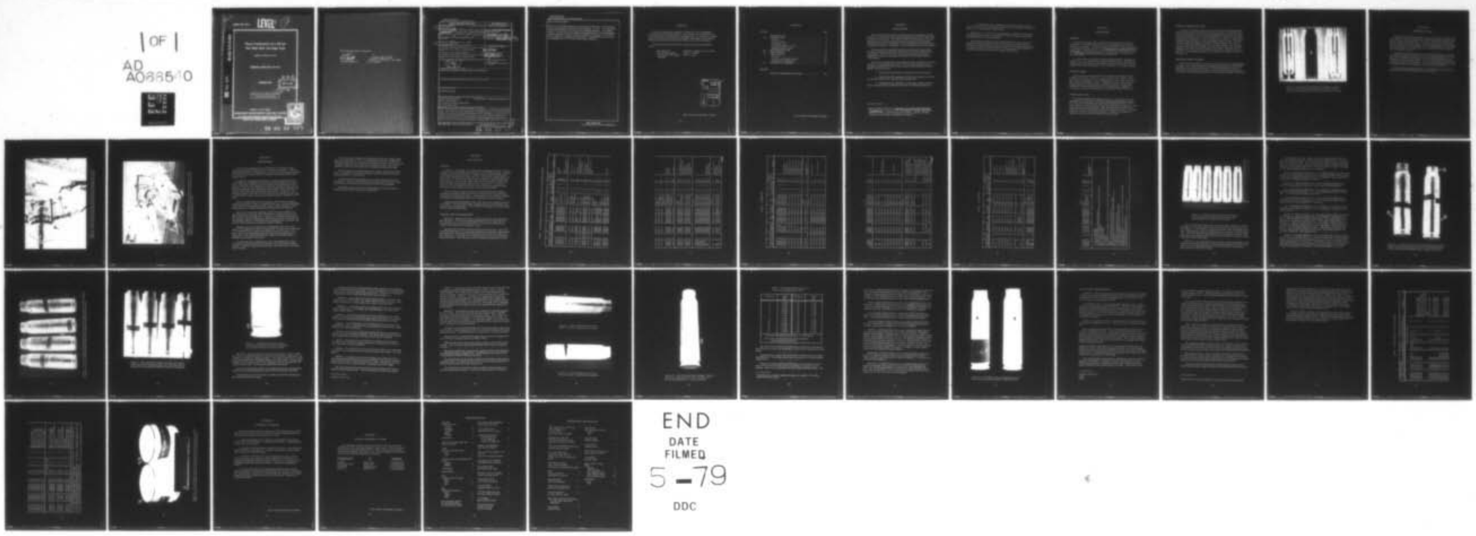

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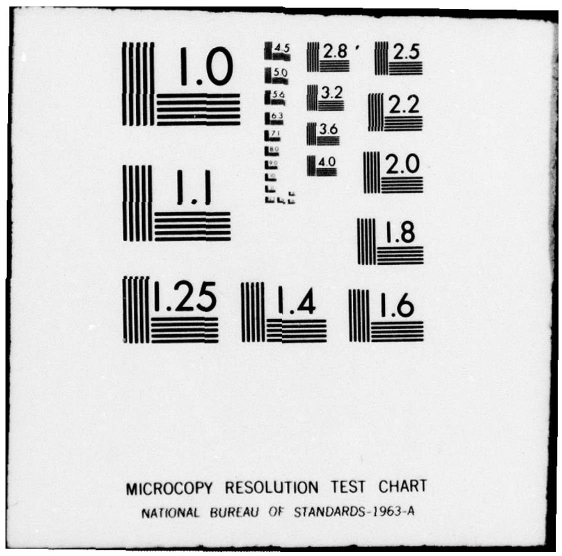
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LEVEL II

Phase II Evaluation of a 30-mm Thin Wall Steel Cartridge Case

GREGORY D. MILLER, 1ST LT, USAF

TECHNICAL REPORT ADTC-TR-79-2

FEBRUARY 1979

Approved for public release;
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ARMAMENT DEVELOPMENT AND TEST CENTER
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This technical report is approved.

H. L. DIMMIG
Technical Director

JACK W. GILLETTE, Col, USAF
Commander

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This report presents results of Phase II testing of a 30-mm steel cartridge case. The steel case was designed for consideration as an alternate to the standard aluminum 30-mm case because of the anticipated increase in projectile velocity and decrease in cost per case. This test was planned to demonstrate performance of the Phase II case design which was necessitated because of case failures in Phase I testing (ADTC-TR-76-11). Case

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Cont → failures at the beginning of this test led to transformation of this effort into an investigation of different case designs. A total of 305 steel case rounds fired at the end of the test incorporated the final case designs tested. Of those fired, the optimal (as determined by its performance) case tested had a lacquer finish and weighed 0.51 pound. Forty-two of these rounds (21 at ambient temperature, 7 conditioned to -65°F, and 14 conditioned to 160°F) were fired without failures.

PREFACE

This test conducted in response to ADTC Air Force Armament Laboratory (AFATL/DLDG) letter, "Test Request for an Evaluation of a 30-mm GAU-8 Thin Wall Steel Cartridge Case," 13 July 1976. Testing began 10 November 1976 and was completed 3 November 1978. Amron Corporation manufactured all of the steel cases for this test effort.

ADTC personnel responsible for testing and report preparation were:

Test Engineer	Gregory D. Miller, 1st Lt, USAF
Test Design Engineer	James C. Griffin
Test Requester/Program Manager	Alvin T. Cox

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SECTION I

INTRODUCTION

The 30-mm thin wall steel cartridge case was designed for consideration as an alternate to the standard aluminum case for the GAU-8 gun system for two reasons. The thinner walls of the steel case versus the aluminum case would increase the internal volume of the cartridge, allowing an increase in propellant and an anticipated resultant increase in projectile velocity. In addition, a case cost reduction was anticipated.

Previous testing[1] exposed deficiencies in the initial case design, including splitting or stretching, which could result in breakage of the gun system. These deficiencies resulted in suspension of the test. Additional testing was requested and initiated to investigate different case designs.

This report documents the investigative testing conducted on several iterations of redesigned steel cases. Various case parameters were changed including outer finish coats and case wall thickness and taper. Specific objectives were:

1. Demonstrate gun system cycling with steel case rounds.

2. Demonstrate the capability of steel case rounds to be fired in, extracted from, and rechambered in hot barrels.

3. Demonstrate the capability of steel case rounds to be fed, fired, and extracted in automatic burst fire at ambient temperature.

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[1] Refer to ADTC-TR-76-11, Evaluation of a 30-mm Thin Wall Steel Cartridge Case, February 1976, Unclassified. Testing reported in ADTC-TR-76-11 is also referred to as Phase I testing. Testing reflected in this report is identified as Phase II.

4. Demonstrate the capability of steel case rounds to be fed, fired, and extracted in automatic burst fire when subjected to hot (160°F), cold (-65°F), and humidity conditioning.

Objectives 1, 2, and 3 were accomplished. The hot and cold conditioning of Objective 4 was accomplished, but the humidity conditioning was deleted by the requesting agency.

To facilitate reporting of test results (Section V), the various configurations of steel cases involved in the overall test were grouped. Groups A through N pertain to those test items (736 rounds) fired during investigations prior to the last group. The last group, Group O (305 rounds), pertains to the last case configurations tested.

SECTION II

DESCRIPTION

GENERAL

The steel cartridge cases provided for this test had various configurations. A tabular summary of the case configurations tested is contained in Section V. A more detailed description of each configuration is contained in AFATL-TR-77-53, 30-MM GAU-8 Thin Wall Steel Cartridge Case, Unclassified, April 1977, ADA053298; and AFATL-TR-78-138, 30-MM GAU-8 Thin Wall Steel Cartridge Case, Unclassified, 19 December 1978.

The final steel cases tested weighed approximately 0.51 pound, as compared to 0.32 pound for the standard aluminum case. The internal volume of the steel case was approximately 14 percent greater than the standard aluminum case (steel - 10.41, aluminum - 9.13 cubic inches).

SURFACE FINISH

Two principal surface finishes were employed throughout the test. A Mader lacquer was one finish for the exterior case surface. This hard finish was applied over a phosphate primer coat. The other finish was a 30 percent Teflon varnish. In addition, several other surface preparations were utilized at the beginning of the test, but were discarded after testing showed them to be unsatisfactory. Additional description of the surface finishes is contained in AFATL-TR-77-53.

PROPELLANT LOAD

Two principal propellant loads were used. The normal load was approximately 178 grams of 5 percent deterred propellant and yielded a 56,000- to 60,000-pound per square inch chamber pressure. An excess pressure load was also utilized during the test to achieve a worst case condition for the steel case. The load was appproximately 159 grams of 2 percent deterred propellant and yielded a 67,000- to 70,000-pound per square inch chamber pressure. These are the loads for regular and excess pressure unless otherwise noted.

PHYSICAL CHANGES TO CASE

A number of changes to the steel case was tested during this effort. Thickness of the case wall (Figure 1) was increased incrementally until a case showing little or no structural degradation was tested. The taper of the wall from the base to the case shoulder was varied to determine the optimum configuration. Heat treatments were altered to obtain steel with decreased hardness, which would reduce case cracking. The head to datum length, the distance measured from the base or head of the case to a reference datum diameter on the case shoulder, was varied to determine the effect on reducing case stretching or cracking. Different punches were used to alter the interior case contour near the base of the case. An in-depth description of the changes is contained in AFATL-TR-78-138.

MANUFACTURING PROCESS

The fabrication method for the thin wall steel case was changed from the blank, cup, and draw process using plate material to a rod, extrude, and draw process using rod material. This allowed better control of dimensions during fabrication and a reduction in waste of raw material. An extensive description of the process is contained in AFATL-TR-78-138.

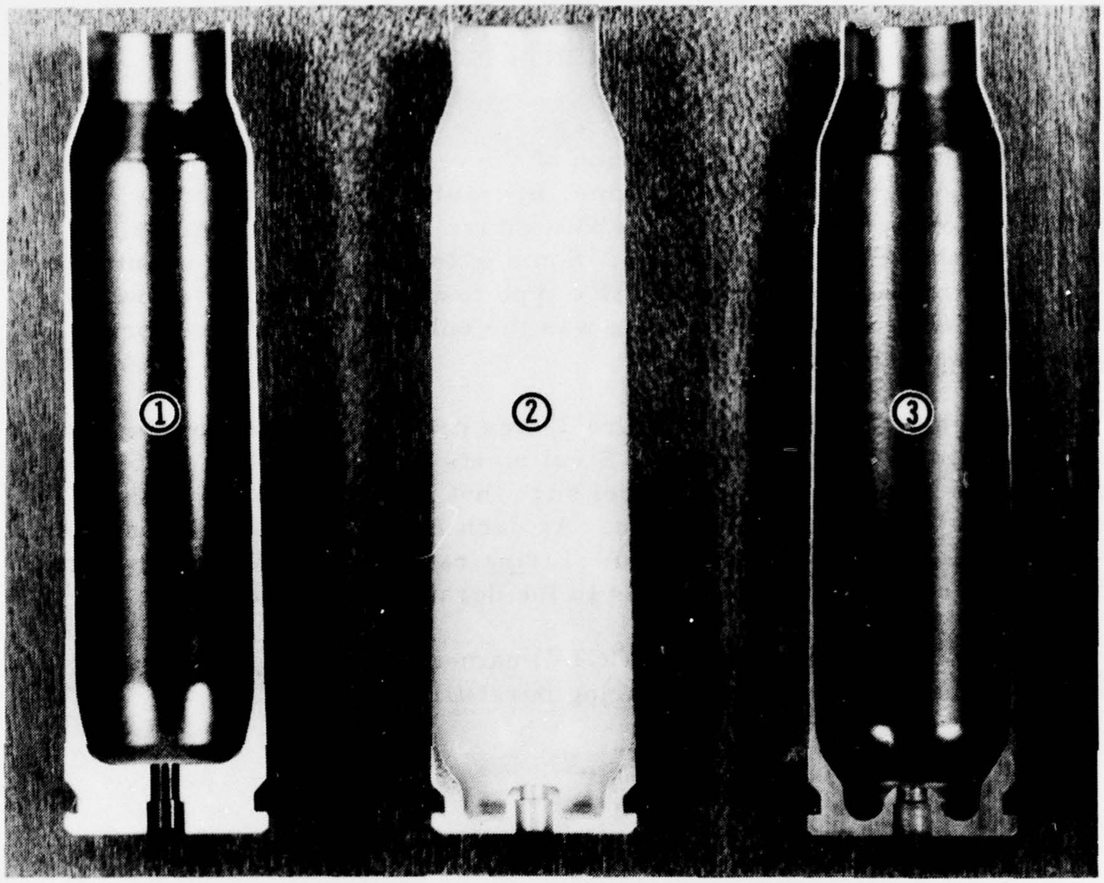

Figure 1. Sectioned cases showing (1) standard aluminum case, (2) steel case from beginning of test effort, and (3) steel case representative of those tested during final testing

SECTION III

INSTRUMENTATION

Instrumentation at the initiation of the test was set up to determine gun firing rate, relative action time, hydraulic pressure and flow, projectile velocity, and dispersion. The nature of the test changed after failure of the initial cases tested. Some of the existing instrumentation was not germane to the investigative type testing that was to follow and thus was deleted. Gun firing rate was the only parameter monitored on all subsequent firings.

A magnetic transducer (Figure 2) was mounted directly on the gun just forward of the gun housing. Steel rivets, approximately 0.25 inch long, were mounted on each barrel such that they would pass by the transducer as the barrels rotated. As each rivet passed the transducer, an electrical pulse was generated. Firing rate was determined by comparing the number of these pulses to the duration of the burst.

A closed circuit television (CCTV) camera (Figure 3) was used to monitor gun system operation during burst firings.

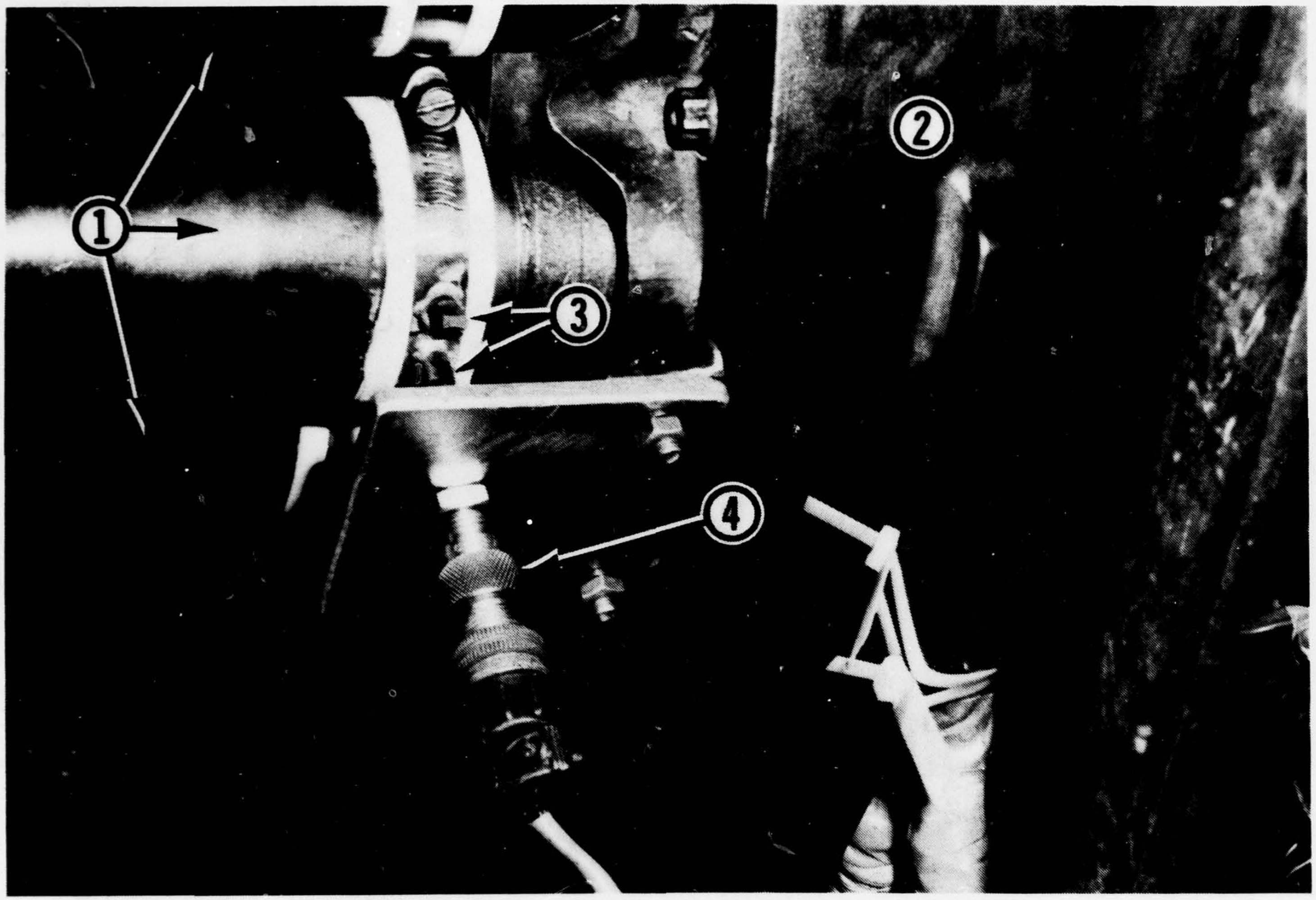

Figure 2. View of (1) gun barrels and (2) housing on prototype GAU-8 gun, showing (3) steel rivets and barrels and (4) magnetic transducer housing

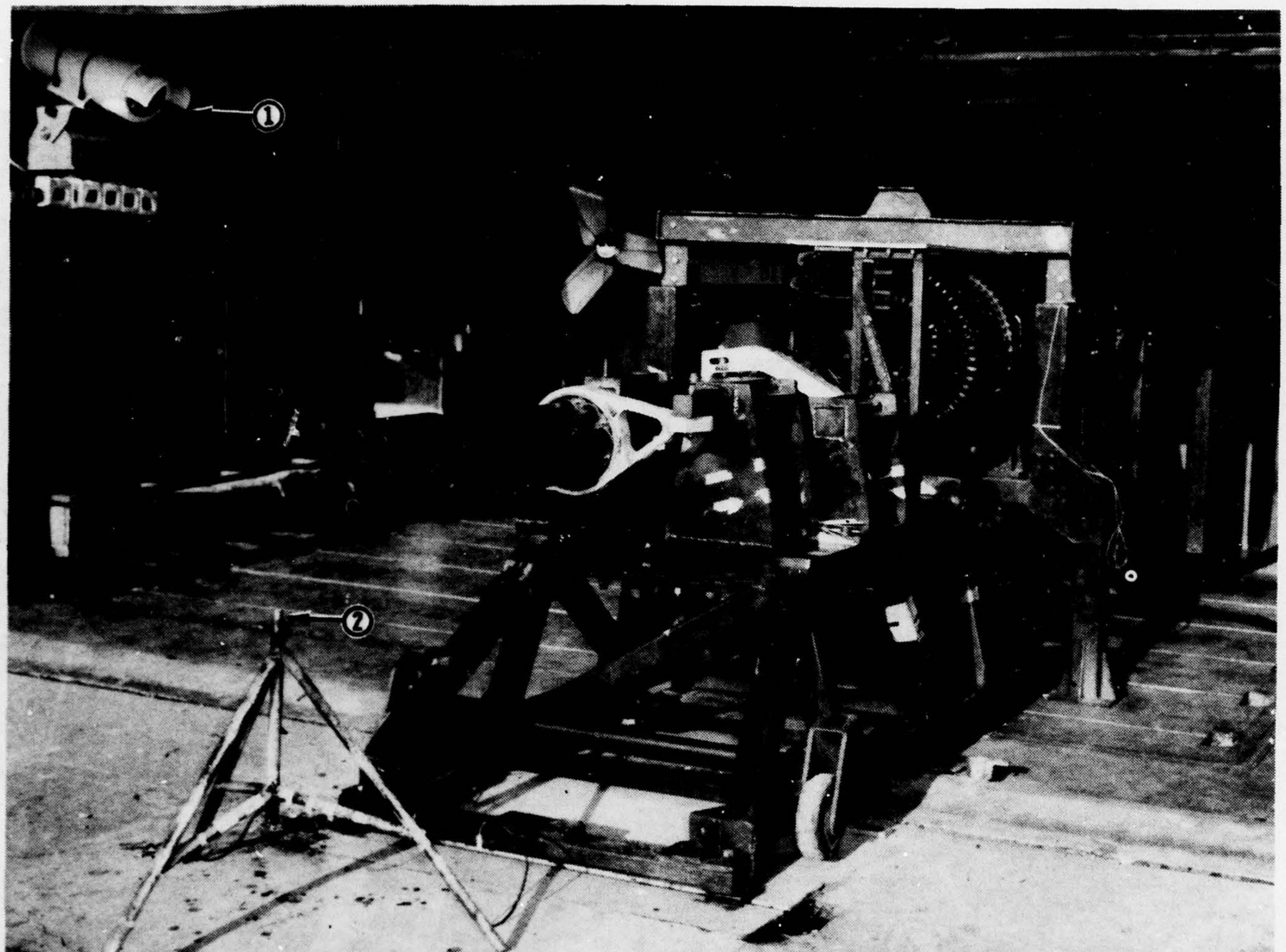

Figure 3. View of prototype GAU-8 gun system, showing (1) closed circuit television camera and (2) blast pressure sensor prior to its removal for subsequent investigative tests

SECTION IV

PROCEDURES

Due to the investigative nature of this test, the number of test rounds per burst was limited to no more than seven rounds. This precluded the possibility of chambering a round in a chamber where portions of a previous case could remain; a situation which could lead to a gun system failure.

In addition, testing was conducted in a sequence where the least severe test was completed first, followed by increasingly more severe tests. Therefore, normal pressure rounds were fired before excess pressure; cold (-65°F) conditioned rounds preceded those that were hot (160°F) conditioned; and rounds were fired at low rate (2,100 shots per minute) before high rate (4,200 shots per minute). Similarly, if in previous testing a particular surface finish or case design proved more successful than another, the more successful finish or design was fired first.

Prior to loading the steel case rounds, each round was visually examined for marks, dents, or ripples on the case. During downloading each round was closely examined for cracks, stretch marks, or dents which may have resulted from either firing the round or handling.

Steel case rounds were manually cycled in the gun system at an extremely low rate to check for interference. Steel case rounds were then cycled at low and high rates. Cases were inspected after each of the cyclings, and projectiles were pulled from the cases to identify any debulleting problems. Debulleting was accomplished by personnel from the Air Force Armament Laboratory (AFATL/DLDL).

Selected cases were temperature conditioned to hot (160°F) or cold (-65°F) temperature prior to being fired. Rounds were conditioned for a nominal 48 hours with the exception of those in Group O. For these cases, the conditioning time was reduced to approximately 16 hours after it was determined that this would not adversely affect or prejudice test conduct and results.

If rounds had been conditioned to hot or cold temperature, they were kept in insulated containers until they were positioned in the gun system. After the rounds were positioned, time was kept to a minimum prior to firing.

On selected tests (Group O), standard aluminum case rounds which had been conditioned to -65°F were positioned and fired. Immediately following this firing, test rounds were positioned and fired using the same chambers which had been cooled by the standard rounds. The cooled chambers collected a small amount of condensation between firings.

The test rounds were then inserted into, fired, and extracted from these wet chambers, thereby duplicating a condition which in previous testing resulted in case failures.

A prototype GAU-8 gun (Figure 3) was used to fire the steel case test rounds. The gun was utilized because of the past history of cracks with the steel cases and the associated possibility of gun damage.

Cardboard targets were set up downrange from the gun muzzle to detect projectile yaws and excessive dispersion.

SECTION V

TEST RESULTS

GENERAL

A total of 1,041 steel case rounds was fired during this test. During testing, the steel cartridge case was observed to fail in a number of modes, depending upon internal pressure, surface finish, hardness of the steel case, thickness and taper of the case wall, temperature conditioning, and firing rate. There were two basic modes of failure, depending upon the above factors. First, case rupture was observed to occur. Second, the case was observed to stretch near the base of the case. Therefore, a major portion of testing was oriented toward finding an optimum finish, hardness, and geometry for the steel case to prevent failure.

Due to the large number of different configurations tested during investigative testing, tests of these steel cases will not be considered in answering test Objectives 3 and 4. Results of these investigative tests are presented in chronological order and are tabulated in part in Table 1.

Following these investigative tests, four final case designs (Group O) were tested. The 305 cases tested displayed improved performance over most of the previous rounds. These results are tabulated in the discussion of the Group O configuration.

EARLIER CASE CONFIGURATIONS

GROUP A. Eighteen steel case rounds were fired at the initiation of this test effort. The cases weighed approximately 0.37 pound and were covered with a 30 percent Teflon coating. Case failures during these firings led to subsequent investigative tests.

Two steel case rounds per barrel were fired at low rate. Two of the 14 rounds misfired due to a firing pin malfunction resulting in light strikes on the primers. Each steel case split when fired at low rate (Figure 4). One round was fired at high rate to confirm that the problem also existed at that condition. This steel case round was almost completely severed.

Table 1. Chronological summary of thin wall steel case ammunition testing

Propellant load	Firing rate[a]	Temperature conditioning	Case design[b]	Case hardness[c]	Case finish[d]	No. tested	No. stretched or cracked	Burst, cycled, or single shot[e]	Remarks
					Group A				
Normal	L	Ambient	Regular steel	Regular	30% Teflon	12	12	SS	All split
Normal	H	Ambient	Regular steel	Regular		1	1	SS	Split
Normal	L	Ambient	Regular steel	Regular	Light oil coat	2	0	SS	
Normal	H	Ambient	Regular steel	Regular	Light oil coat	1	0	SS	
Normal	H	Ambient	Regular steel	Regular		1	1	SS	Split
Normal	H	Ambient	Regular steel	Regular	Light oil coat	1	0	SS	Fired in same barrel as previous round
					Group B				
Normal	L	Ambient	Regular steel	Regular	30% Teflon w/Fluoroglide	4	4	SS	All cracked
Normal	H	Ambient	Regular steel	Regular	30% Teflon w/Fluoroglide	1	1	SS	Ruptured
Normal	L	Ambient	Regular steel	Regular		2	2	SS	Cracked
Normal	SL, L, H[f]	Ambient	RHTD	Regular	30% Teflon	3	3	SS	First two cracked; third split lengthwise
Normal	SL, L, H[f]	Ambient	Regular steel	Regular	30% Teflon over zinc	3	3	SS	All three cracked
Normal	SL, L, H[f]	Ambient	Regular steel	Regular	Mader lacquer	3	2	SS	Two stretched
Normal	SL, L, H[f]	Ambient	Regular steel	Regular	100% Teflon	3	3	SS	Three cracked
Normal	SL, L, H[f]	Ambient	Regular steel	Regular	100% Teflon w/Fluoroglide	3	3	SS	First stretched, other two cracked
Normal	SL, L, H[f]	Ambient	Regular steel	Reduced	30% Teflon	3	3	SS	Two stretched, third split
High	SL, L, H[f]	Ambient	Regular steel	Regular	Fluoroglide (oiled)	3	0	SS	
Normal	H	Ambient	RHTD	Regular	Oiled	1[g]	0	B-1	
High	H	Ambient	Regular steel	Regular	Oiled	1[g]	0	B-1	
Normal	H	Ambient	Regular steel	Regular		2[g]	0	B-1	
Normal	H	Ambient	RHTD	Regular	Oiled	1[g]	0	B-2	
Normal	H	Ambient	Regular steel	Regular	30% Teflon (oiled)	3[g]	0	B-2	
Normal	H	Ambient	Regular steel	Regular	Mader lacquer	1[g]	0	B-2	
Normal	H	Ambient	Regular steel	Regular	30% Teflon	2[g]	2	B-2	Both split
Normal	H	Ambient	Regular steel	Regular	Mader lacquer	1[g]	0	B-3	
Normal	H	Ambient	Regular steel	Regular	100% Teflon	1[g]	0	B-3	

Normal	H	Ambient	Regular steel	Regular	100% Teflon (oiled)	1[6]	0	B-3	
Normal	H	Ambient	Regular steel	Regular	100% Teflon w/Fluoroglide	1[6]	0	B-3	
Normal	H	Ambient	Regular steel	Regular	100% Teflon w/Fluoroglide (oiled)	1[6]	0	B-3	
Normal	H	Ambient	Regular steel	Reduced	w/Fluoroglide	1[6]	1	B-3	Cracked
Normal	H	Ambient	Regular steel	Reduced	wo/Fluoroglide	1[6]	1	B-3	Stretched
Normal	H	Ambient	Regular steel	Regular	w/Fluoroglide	5[6]	2	B-4	Stretched
Normal	H	Ambient	Regular steel	Regular	Zinc plate w/Fluoroglide	2[6]	0	B-4	
Normal	H	Ambient	Regular steel	Regular		7[6]	7	B-5	All cracked
					Group C				
Normal	L	Ambient	Regular steel	Reduced	Teflon	3	0	B-1	
Normal	H	Ambient	Regular steel	Reduced	Teflon	3	1	B-2	One case split
Normal	L	Ambient	Regular steel	Regular	Mader lacquer	3	3	B-3	Two split, one stretched
Normal	H	Ambient	Regular steel	Regular	Mader lacquer	7	7	B-4	Four cracked, three stretched
Normal	L	Ambient	Regular steel	Reduced	Mader lacquer	3	2	B-5	Two stretched
Normal	H	Ambient	Regular steel	Reduced	Mader lacquer	7	2	B-6	Two stretched
Normal	L	Ambient	Regular steel	Reduced	Lacquer (black)	3	1	B-7	One mild stretch
Normal	H	Ambient	Regular steel	Reduced	Lacquer (black)	7	6	B-8	One cracked, five stretched
					Group D				
Normal	L	Ambient	Regular steel	Reduced	Mader lacquer	1	0	B-1	
Normal	L	Ambient	Regular steel	Regular	Mader lacquer	5	0	B-1	
Normal	H	Ambient	Regular steel	Regular	Mader lacquer	6	0	B-2	
Normal	L	Ambient	Regular steel	Regular	Mader lacquer	7	0	B-3	
Normal	L	Ambient	Regular steel	Reduced	Mader lacquer	7	0	B-4	
Normal	H	Ambient	Regular steel	Reduced	Mader lacquer	7	0	B-5	
Normal	H	Ambient	Regular steel	Reduced	Mader lacquer	6	0	B-6	
High	L	Ambient	Regular steel	Reduced	Mader lacquer	6	6	B-7	All stretched
High	H	Ambient	Regular steel	Reduced	Mader lacquer	7	7	B-8	All stretched
		Ambient	Regular steel	Reduced	Mader lacquer	4		B-9	Misfired rounds
					Group E				
High	L	Ambient	Regular steel	Reduced	Mader lacquer	7	7	B-1	Five cracked, two stretched
High	L	Ambient	Regular steel	Regular	Mader lacquer	7	7	B-2	All stretched
High	H	Ambient	Regular steel	Reduced	Mader lacquer	7	7	B-3	All cracked
High	H	Ambient	Regular steel	Regular	Mader lacquer	7	7	B-4	Four stretched, three cracked

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Table 1. (Continued)

Propellant load	Firing rate[a]	Temperature conditioning	Case design[b]	Case hardness[c]	Case finish[d]	No. tested	No. stretched or cracked	Burst, cycled, or single shot[e]	Remarks
					Group F				
Normal	L	-65°F 48 hr	Regular steel	Regular	Mader lacquer	7	0	B-1	
Normal	L	-65°F 48 hr	Regular steel	Regular	Mader lacquer	7	0	B-2	
Normal	H	-65°F 48 hr	Regular steel	Regular	Mader lacquer	7	0	B-3	
Normal	H	-65°F 48 hr	Regular steel	Regular	Mader lacquer	7	0	B-4	
Normal	L	Ambient	Regular steel	Regular	Mader lacquer	7	4	B-5	Four stretched
Normal	H	Ambient	Regular steel	Regular	Mader lacquer	7	2	B-6	Two stretched
Normal	L	160°F 48 hr	Regular steel	Regular	Mader lacquer	7	2	B-7	One stretched, one cracked
Normal	L	160°F 48 hr	Regular steel	Regular	Mader lacquer	7	4	B-8	Three stretched, one cracked
Normal	H	160°F 48 hr	Regular steel	Regular	Mader lacquer	7	6	B-9	Four stretched, two cracked
Normal	H	160°F 48 hr	Regular steel	Regular	Mader lacquer	7	4	B-10	Three stretched, one cracked
Normal	L	Ambient	Regular steel	Regular	Mader lacquer	14	3	B-11	Two stretched, one cracked
Normal	H	Ambient	Regular steel	Regular	Mader lacquer	14	7	B-12	First seven cracked
					Group G				
Normal	L	Ambient	Regular steel	Regular	Silicone	7	7	B-1	Six cracked, one stretched
					Group H				
Normal	L (1,800)	Ambient	Regular steel +0.002 in.[h]	Regular	Mader lacquer	7	2	B-1	Two stretched
Normal	L (2,000)	Ambient	Regular steel +0.008 in.[h]	Regular	Mader lacquer	7	0	B-2	
Normal	L (1,400)	Ambient	Regular steel +0.008 in.[h]	Regular	Mader lacquer	7	0	B-3	One round misfired
Normal	L (2,200)	Ambient	Regular steel +0.002 in.[h]	Regular	Mader lacquer	7	0	B-4	
Normal	H (3,200)	Ambient	Regular steel +0.002 in.[h]	Regular	Mader lacquer	7	0	B-5	

					Group I				
Normal		Ambient	Regular steel	Regular	Mader lacquer	7	0	B-1	
Normal		Ambient	Regular steel	Regular	Mader lacquer	7	0	B-2	
Normal		Ambient	Regular steel	Regular	Mader lacquer	7	0	B-3	
Normal		Ambient	Regular steel	Regular	Mader lacquer	1	0	SS	
					Group J				
High	L	Ambient	Regular steel	Regular	Mader lacquer wo/B[i]	7	0	B-1	
High	L	Ambient	Regular steel	Regular	Mader lacquer w/B[j]	7	0	B-2	
High	L	Ambient	Regular steel	Regular	Teflon	7	7	B-3	One stretched, five cracked, one separated
Normal	L	Ambient	Regular steel	Regular	Mader lacquer wo/B[i]	7	0	B-4	
Normal	H	Ambient	Regular steel	Regular	Mader lacquer wo/B[i]	7	0	B-5	
Normal	H	Ambient	Regular steel	Regular	Mader lacquer wo/B[i]	7	0	B-6	
Normal	L	Ambient	Regular steel	Regular	Mader lacquer w/B[j]	7	1	B-7	One stretched
Normal	H	Ambient	Regular steel	Regular	Mader lacquer w/B[j]	7	0	B-8	
Normal	H	Ambient	Regular steel	Regular	Mader lacquer w/B[j]	7	0	B-9	
					Group K				
Normal	L	Ambient	Regular steel	Regular	Mader lacquer	14		C-1, 2	Cycled then debulleted
Normal	H	Ambient	Regular steel	Regular	Mader lacquer	14		C-3, 4	Cycled then debulleted
Normal	L	Ambient	Regular steel	Regular	Mader lacquer	14	14	B-1, 2	Bursts of seven; seven cracked, seven stretched
Normal	L	Ambient	Regular steel	Regular	Mader lacquer (oiled)	14	0	B-3, 4	Bursts of seven
Normal	L	Ambient	Regular steel	Regular	Mader lacquer	42	12	B-5, through 10	Fired with minimum time between bursts. Last seven rounds were re-chambered for chamber temperature test. One cracked, 11 stretched.
Normal		-65°F 48 hr	Regular steel	Regular	Mader lacquer	28	2	B-11, through 14	Bursts of seven; two cases split lengthwise
Normal		160°F 48 hr	Regular steel	Regular	Mader lacquer	28	28	B-15, through 18	Bursts of seven; 8 cracked, 20 stretched
High		Ambient	Regular steel	Regular	Mader lacquer	21	21	B-19, through 21	Bursts of seven; 14 cracked, 7 stretched

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Table 1. (Concluded)

Propellant load	Firing rate[a]	Temperature conditioning	Case design[b]	Case hardness	Case finish[d]	No. tested	No. stretched or cracked	Burst, cycled, or single shot[e]	
					Group L				
Normal		Ambient	SHTD, OP	Regular	Mader lacquer, thick	7	7	B-1	All cracked
High		Ambient	SHTD, OP	Regular	Mader lacquer, thick	7	7	B-2	All cracked
Normal	L	Ambient	SHTD, OP	Regular	Mader lacquer, thin	7	7	B-3	All cracked
Normal	L	Ambient	LHTD, OP	Regular	Mader lacquer, thin	6	6	B-4	All cracked
Normal	L	Ambient	LHTD, OP	Regular	Mader lacquer, thin	6	6	B-5	Five cracked, one stretched
Normal	L	Ambient	SHTD, NP	Regular	Mader lacquer, thin	7	7	B-6	Three cracked, four stretched
High	L	Ambient	SHTD, NP	Regular	Mader lacquer, thin	7	7	B-7	Three stretched, two cracked, two stretched (gun jam)
Normal	L	Ambient	LHTD, NP	Regular	Mader lacquer, thin	7	7	B-8	All stretched
		Ambient	Standard aluminum					B-9	Aluminum control rounds
High		Ambient	LHTD, NP	Regular	Mader lacquer, thin	7		B-10	Case rupture; gun stoppage
					Group M				
Normal	L	Ambient	Regular steel	Regular	Mader lacquer	14	0	B-1, 2	
Normal	H	Ambient	Regular steel	Regular	Mader lacquer	7	0	B-3	
High	L	Ambient	Regular steel	Regular	Mader lacquer	7	0	B-4	
High	H	Ambient	Regular steel	Regular	Mader lacquer	7	0	B-5	
High	L	Ambient	Regular steel	Regular	Teflon	7	0	B-6	

				Group N					
Normal	L	-65°F 48 hr	Regular steel	Regular	Teflon	7	0	B-1	
Normal	H	-65°F 48 hr	Regular steel	Regular	Teflon	7	0	B-2	
Normal	L	-65°F 48 hr	Regular steel	Regular	Mader lacquer	7	0	B-3	
Normal	H	-65°F 48 hr	Regular steel	Regular	Mader lacquer	7	0	B-4	
Normal	L	+160°F 48 hr	Regular steel	Regular	Teflon	7	0	B-5	Gun stoppage; case separation

[a] L - low rate (2,100 SPM).
H - high rate (4,200 SPM).
Exceptions to above SPMs are contained in parenthesis.
SL - slower than L (round positioned approximately four positions away from gun chamber).

[b] RHTD - reduced head to datum.
SHTD - short head to datum.
LHTD - long head to datum.
OP - old punch.
NP - new punch.
Note: Regular steel case designs in Groups A through G weighed 0.37 lb; regular steel case designs in Groups H through N weighed 0.45 lb.

[c] Regular case hardness on the RN 30 scale was 57 to 60.

[d] Lacquer for Group K was from a different container than previous groups.
Note: Description of Fluoroglide coating (Group B) is contained in AFATL-TR-77-53.

[e] SS - single shot.
B - burst; number following indicates burst number.
(Note that some bursts included rounds of various configurations.)
C - cycled; number following indicates group of rounds cycled.

[f] One round fired at each rate.

[g] Rounds fired at the end of a 49-round high rate burst of standard aluminum case ammunition.

[h] Wall thickness increased.

[i] Case surface was not blasted with glass beads.

[j] Case surface was blasted with glass beads to remove imperfections.

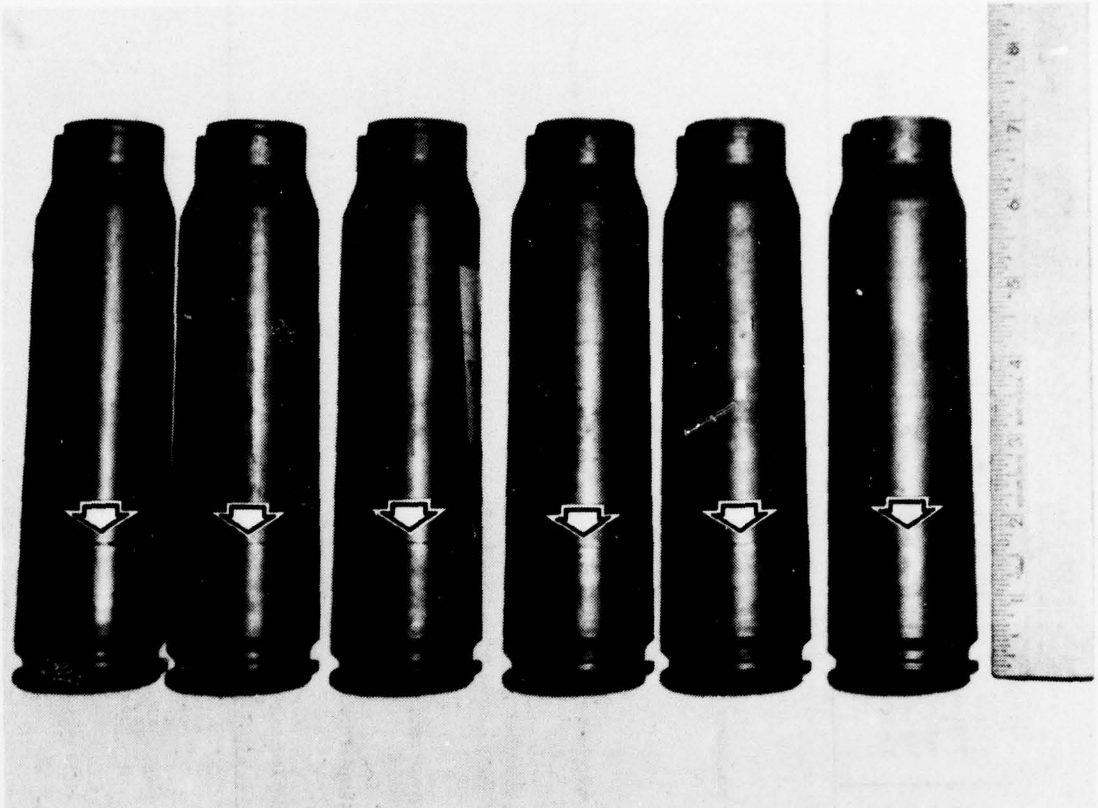

Figure 4. First six cases (Group A) of 14 fired at low rate showing (arrows) circumferential split approximately 1 5/8 inches from the base

After examining the split cases, four steel case rounds were coated with light oil in an attempt to reduce the friction forces between the case and chamber. Two rounds were fired at low rate, with no splitting occurring. Subsequently, one oiled round and one dry round were fired at high rate. The oiled round did not split but the dry round did. Another oiled round was fired at high rate in the same barrel as the previous dry round. This oiled round did not split.

GROUP B. The next iteration of steel case rounds investigated was of different case finish materials. Gun oil and Fluoroglide (see AFATL-TR-77-53) were two lubricants applied to the case surfaces in this group. Sixty steel case rounds were fired.

Twenty-eight steel case rounds of various configurations (Table 1) were fired singly. Nineteen rounds cracked or split (Figures 5, 6, and 7) and five rounds stretched. Four rounds had no visible structural degradation. Three of these were regular steel rounds (Figure 6) loaded for high chamber pressure and coated with a thin film of oil. The other was finished with Mader lacquer (Figure 7) over phosphate.

Thirty-two steel case rounds were fired in five bursts. The steel case rounds in each burst were preceded by 49 standard aluminum cased rounds. Eleven steel cases split or cracked and four stretched. The remaining 17 rounds had no visible structural degradation.

GROUP C. Thirty-six steel case rounds of varying hardness and different finish coats were fired in eight bursts at low and high rate.

Six reduced hardness cases with Teflon finish were fired at low and high rates (three at each rate). One of the cases split when fired at high rate. The other five showed no degradation.

Twenty rounds (10 each at regular and reduced hardness) finished with Mader lacquer were fired in four bursts. Two split, four cracked, eight stretched, and six showed no degradation.

Ten rounds with black lacquer were fired (three at low rate, seven at high rate) in two bursts. Four showed no degradation, one cracked, and five stretched.

GROUP D. Fifty-six steel cases with Mader lacquer finish were fired in nine bursts. Eighteen cases (regular hardness) fired during the first three bursts showed no structural degradation. Two rounds failed to fire because the primers were set too deep. Twenty-one rounds (reduced hardness, regular pressure) were fired at low (eight rounds) and high (13 rounds) rate with no evidence of structural degradation. One round misfired. Thirteen rounds (reduced hardness, high pressure) were fired at low (six rounds) and high (seven rounds) rate. All cases stretched near the base (Figure 8). One round misfired.

GROUP E. Twenty-eight steel case rounds with Mader lacquer finish were fired in four bursts of seven. Of seven rounds with reduced hardness fired at low rate, five cracked and two stretched. Of seven rounds with reduced hardness fired at high rate, all seven stretched. All seven rounds with regular hardness fired at low rate cracked, while four of the same rounds fired at high rate stretched, and the remaining three cracked.

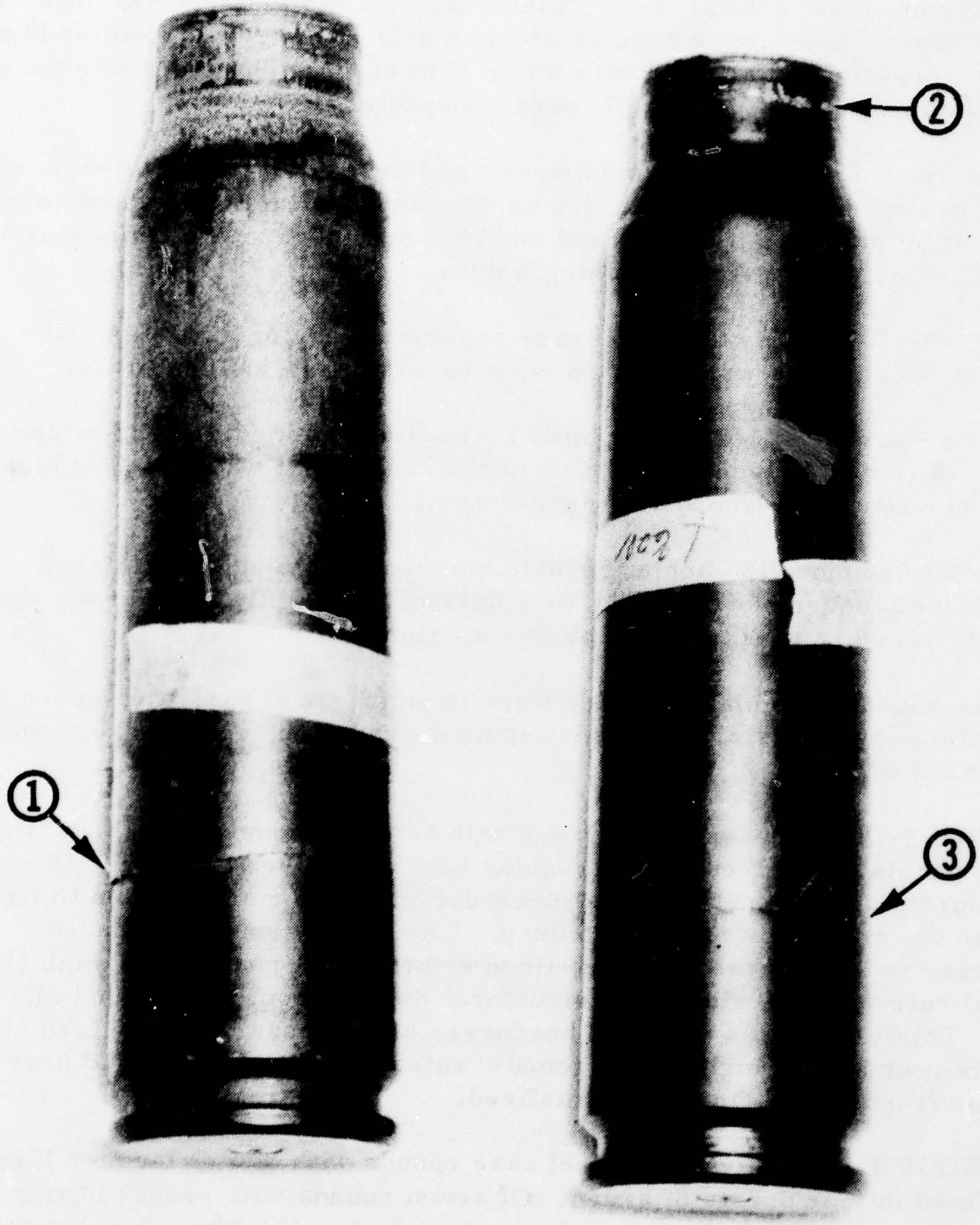

Figure 5. Two steel cases from Group B showing (1) crack in regular steel case fired at low rate and case coated with 100 percent Teflon with (2) flaking of case coating and (3) crack

Figure 6. Three steel case rounds from Group B loaded for high pressure and one reduced hardness steel case with 30 percent Teflon over phosphate showing crack (arrow)

Figure 7. Four cases from Group B showing (1) cracks in cases coated with 30 percent Teflon over zinc plate and (2) stretch in a case coated with Mader lacquer over phosphate

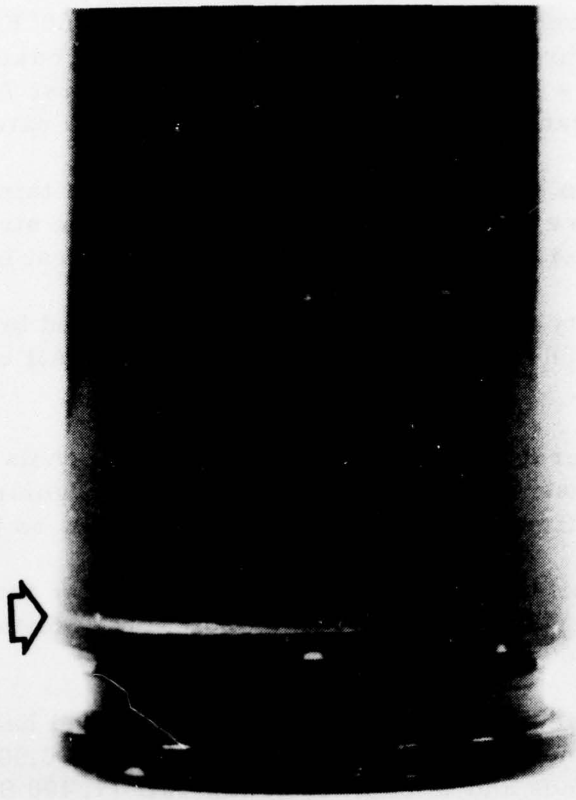

Figure 8. Typical Group D Mader lacquer finished case which was loaded for high pressure, showing stretch near base (arrow)

GROUP F. Ninety-eight steel case rounds with Mader lacquer finish were fired at ambient temperature and after temperature conditioning. All rounds were loaded for regular pressure. The first 10 bursts had 7 rounds per burst, and the last two bursts contained 14 rounds each. Twenty-eight rounds were fired after cold (-65°F) conditioning at low and high rate (14 rounds at each rate). No structural degradation was noted.

Four of seven ambient temperature rounds fired at low rate stretched. Two of seven ambient temperature rounds fired at high rate stretched.

Fourteen cases were fired at low rate after hot (160°F) conditioning. Four stretched and two cracked.

Fourteen cases were fired at high rate after hot (160°F) conditioning. Seven stretched and three cracked. Two of 14 ambient cases stretched and and 1 cracked during a burst firing at low rate. The first 7 of 14 ambient temperature cases cracked during a burst firing at high rate.

GROUP G. Seven steel case rounds sprayed with a thin film of silicone[2] were fired at low rate. Six cases cracked and one stretched. Additional rounds were not fired due to the results of the first burst.

GROUP H. Thirty-five steel case rounds were fired in five bursts of seven rounds each. The variable was wall thickness. All cases had a Mader lacquer finish.

Burst 1. This burst was fired at low rate [1,800 shots per minute (SPM)]. Wall thickness was 0.002 inch greater than regular test rounds. Two of seven rounds fired showed visible stretch marks on the cases.

Burst 2. The wall thickness was 0.008 inch greater than that of the original test rounds. All cases were in satisfactory condition after being fired at low rate (2,000 SPM).

Burst 3. Six of seven rounds fired during this burst had satisfactory cases. The other round was a misfire. The cases were 0.008 inch thicker than original test rounds and were fired at low rate (1,400 SPM).

Burst 4. All cases were in satisfactory condition after this burst. The cases were 0.002 inch thicker than those of original test rounds and were fired at low rate (2,200 SPM).

Burst 5. The last burst of seven rounds was at high rate (3,200 SPM). The cases were 0.002 inch thicker than the original test rounds. No cases failed.

GROUP I. During the next series of testing, 22 rounds were fired. The case wall thickness was increased 0.008 inch in the critical area (1.6 inches from the base of the case) for these rounds. Rounds were fired in three bursts of seven rounds with the remaining round fired singly.

One round from the second burst showed some flaking of the lacquer near the case mouth and neck. No stretch marks or cracks were noted.

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[2] AFATL-TR-77-53.

GROUP J. Sixty-three rounds [28 each, Mader lacquer with and without surface preparation (blasting with glass beads to remove surface imperfections), and 7 with Teflon coating] were fired during the next series of testing. Rounds were fired in seven-round bursts in accordance with the schedule in Table 1. Inspection of rounds after the first two bursts revealed no discrepancies. All of the Teflon case rounds fired during the third burst failed. One round stretched, five rounds cracked, and one round separated (Figures 9 and 10). All rounds in the remaining bursts had good cases except one case in the seventh burst, which had a stretch mark.

GROUP K. One hundred seventy-five rounds were tested during this series of tests. Due to the expected success of these cases, debullet pull force was determined before firing these rounds. As a result of the low debullet pull forces (Table 2) recorded after cycling the rounds, no high rate firings were conducted. The principal change to the cases since the last tests conducted included tempering the steel at a different temperature, resulting in a reduced hardness.

During the cycle and debullet pull test, four sets of seven rounds each were cycled. Rounds making up the first set all had wrinkles in the necks, but good crimps. Projectile pull was recorded and is reported in Table 2.

Rounds from the second set had slight dents in the case shoulder and one projectile was loose (could be rotated in case).

Slight shoulder dents were again noted in cases from the third set of rounds. Four of seven rounds had projectiles which could be rotated in the case.

All cases cycled in the fourth set of rounds had dents in the shoulder. One case had a severe shoulder dent. Six projectiles were loose to the extent that they could be rotated in the case.

The first burst of seven rounds resulted in two radial cracks and five stretched cases. All stretches and cracks occurred at approximately 2.1 inches from the base of the case (Figure 11).

The second seven-round burst again revealed structural failures at the same point above the base. Five cases cracked and two stretched.

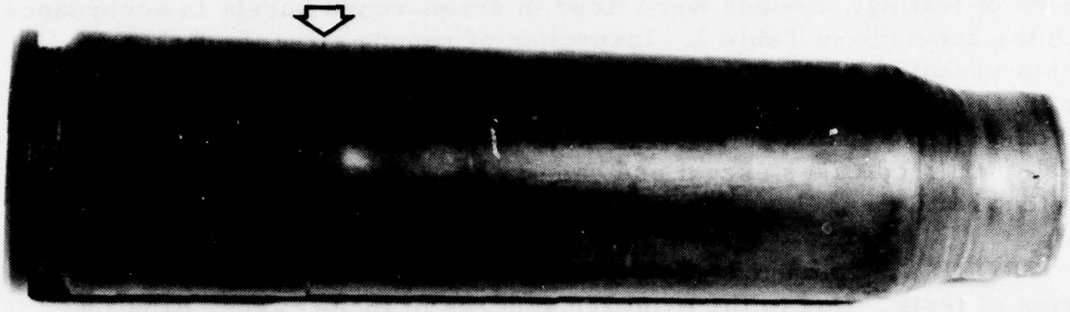

Figure 9. Teflon coated steel case from burst 3 of Group J showing crack (arrow)

Figure 10. Teflon coated steel case from burst 3 of Group J showing case separation

Figure 11. Typical Group K Mader lacquer finished case which was fired at low rate, showing crack (arrow) approximately 2.1 inches from base

Table 2. Recorded debullet pull forces from cycled rounds from Group K

Round no.	Pull[a] (lbf)	Round no.	Pull[a] (lfb)
1	1,480	15	1,625
2	1,775	16	1,575
3	1,475	17	1,500
4	1,650	18	1,675
5	2,025	19	1,700
6	1,475	20	1,700
7	1,650	21	1,375
8	1,825	22	1,735
9	1,775	23	1,540
10	1,425	24	1,230
11	1,900	25	1,625
12	1,475	26	1,675
13	1,350	27	1,475
14	1,400	28	1,600

[a] The specified minimum pull force is 1,900 pounds.

Note: Data obtained from Air Force Armament Laboratory (AFATL/DLDL)

The next two bursts of seven rounds were coated with a thin film of gun oil[3] prior to firing. No stretches or cracks were noted on any of the cases.

Following these bursts, the barrels were changed because of safety considerations. Projectile yaws of up to 90 degrees occurred using the old barrels.

Forty-two regular pressure rounds were fired in bursts of seven each. Bursts were fired as quickly as possible to maximize barrel heating. Cases were inspected in the gun chuting between bursts. The

[3] Lubricating oil, general purpose (weapons oil, light), VV-L-800a, FSN 9150-00-231-6689.

final seven rounds were returned after inspection to the hot gun chambers for a 10-minute soak period at existing chamber temperature. The chamber temperature had no visible effect on the case finish. Of the 42 rounds fired, 11 showed evidence of stretching and 1 was cracked. The remaining cases revealed no defects other than normal handling marks.

Twenty-eight rounds were fired after cold conditioning at -65°F for 48 hours. Firing was in seven-round bursts separated by minimal time required for case inspection. Two cases split lengthwise from the case mouth (Figure 12). All other cases were in satisfactory condition.

Twenty-eight rounds were hot conditioned at 160°F for 48 hours. These were fired in bursts of seven rounds and downloaded after each burst. Of the cases tested, 8 were cracked and 20 were stretched.

Twenty-one high pressure ambient temperature rounds were fired in seven-round bursts. Cases were downloaded following each burst. Fourteen cases were cracked and seven were stretched.

GROUP L. Sixty-one steel case rounds with Mader lacquer finish were fired in bursts of seven (or six) rounds at low rate. Variables between cases (Table 1) included high or regular pressure, long or short head to datum lengths, and use of a new or old punch in making the cases. Of the rounds fired in the first six bursts, all cracked except five which stretched (one in burst 5 and four in burst 6). During burst 7, two cases separated (jamming the gun), three stretched, and two cracked. All seven rounds in burst 8 stretched. The cases in burst 9 were aluminum control rounds which neither stretched nor cracked. A case rupture during burst 10 resulted in a gun stoppage.

GROUP M. A total of 42 steel case rounds with Mader lacquer (35 cases) and DeBeers Teflon (7 cases) finishes was loaded for high or regular pressure and fired at low or high rate (Table 1). All cases were in satisfactory condition.

GROUP N. A total of 35 steel case rounds with Mader lacquer (14 cases) and DeBeers Teflon (21 cases) was fired at low and high rate after cold (-65°F) and hot (160°F) conditioning. The first four bursts were fired satisfactorily. A case separation during the fifth burst (hot, Teflon, at low rate) resulted in a gun stoppage.

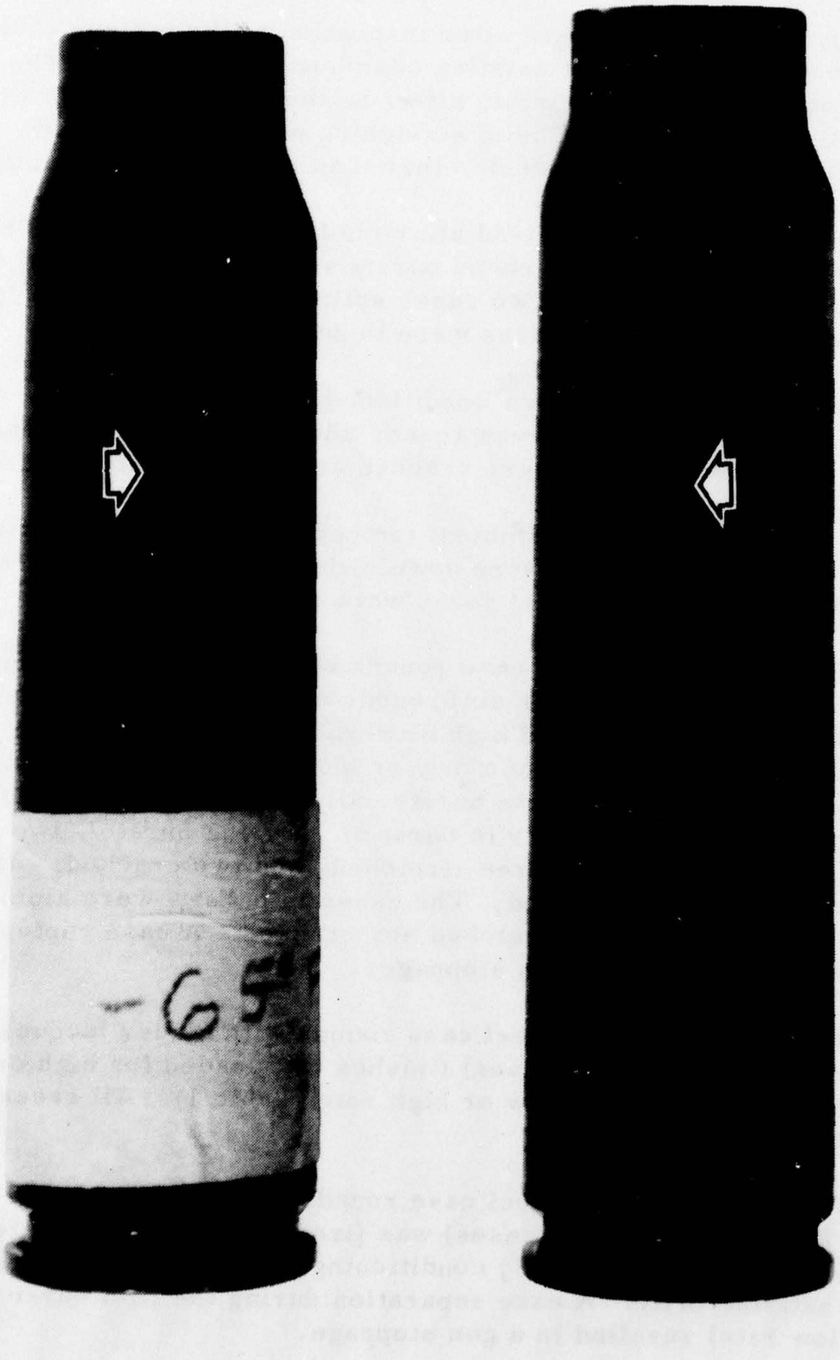

Figure 12. Two Mader lacquer finished steel cases from Group K showing lengthwise splits (arrows)

FINAL STAGE CONFIGURATION

GROUP O. The final iteration of steel cases encompassed a number of different variables including two different surface finishes, different case wall thicknesses, and two propellant loads. Results of the 305 cases tested are summarized in Table 3.

Dry Chamber Tests. Two hundred fifty-eight steel case rounds were fired during tests using dry chambers. Of these, 168 contained a propellant load determined to yield a normal (approximately 60,000-pound per square inch) chamber pressure. During low rate firings, 42 ambient rounds (7 each of three different designs with both lacquer and Teflon finishes) were fired in seven-round bursts. All cases were in satisfactory condition.

Another 42 rounds of identical configuration were fired after being temperature conditioned at -65°F. All cases were in satisfactory condition.

The remaining 84 rounds with a normal propellant load were temperature conditioned to 160°F. The first 42 were fired at low rate. Fourteen of these were of case Design A[4] (7 each with lacquer and Teflon finishes) and all cases were in satisfactory condition. Seven rounds of case Design B[5] with lacquer finish were fired. Two of these revealed slight stretch marks. Six of seven of the same case design with Teflon finish had slight stretches.

Fourteen rounds of case Design C[6] (7 each finished with lacquer and Teflon) were fired, with all 14 showing stretches. It should be noted that the seven lacquer finished rounds were fired after seven cold conditioned rounds, resulting in possible wet chambers (see Section IV). This could have contributed to the stretching.

The remaining 42 hot temperature conditioned rounds were fired at high rate (4,200 SPM). Fourteen rounds of case Design A (7 each finished with lacquer or Teflon) were fired, after which none of the lacquer finished rounds showed signs of stretch. Three of the seven

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[4] AFATL-TR-78-138
[5] Ibid
[6] Ibid

Teflon finished rounds had light stretches. The other 28 rounds were of case Designs B and C. Each design had seven lacquer and seven Teflon finished cases. All 28 exhibited slight stretches after the rounds were fired.

The remaining 90 rounds which were fired from dry chambers were loaded to achieve excess pressure (approximately 70,000 pounds per square inch) when fired. Thirty-four of these were at ambient temperature and were fired at low rate. The 14 rounds with case Design A (seven lacquer and seven Teflon finished cases) were satisfactory. Of the rounds having case Design B, the three with a lacquer finish were satisfactory, while two of the three with a Teflon finish showed light stretches. Of the rounds having case Design C, two of seven rounds with lacquer finish had light stretches, while all seven rounds with Teflon finish showed light stretches.

Forty-two of the ambient, excess pressure rounds were fired at high rate. Of the 14 rounds fired with case Design A (seven lacquer and seven Teflon finished cases), one Teflon case showed a light stretch. Of the 14 rounds fired having case Design B (seven lacquer and seven Teflon finished cases), light stretches were noted on two of the lacquer cases and six of the Teflon cases. Of the remaining rounds having case Design C (seven lacquer and seven Teflon finished cases), light stretches were noted on three lacquer and five Teflon cases.

The remaining rounds of the 258 fired in dry chambers were ambient rounds which were loaded for excess pressure. These 14 rounds had case Design D[7] and were fired at low rate. Two of the seven cases with a lacquer finish and one of the seven cases with Teflon finish had stretches.

Wet Chamber Tests. Forty-seven test rounds were fired during wet chamber tests (as described in Section IV). All rounds were loaded to achieve excess chamber pressures (68,000 to 70,000 pounds per square inch) and were fired at ambient temperature and at low rate.

Of the 12 rounds fired having case Design A (six lacquer and six Teflon finished cases), light stretches were noted on three of the lacquer

[7] These were 0.45 lb cases similar to those fired in previous groups.

cases and five of the Teflon cases. Of the 12 rounds fired having case Design B (six lacquer and six Teflon finished cases), four lacquer cases had obvious stretches and the other two had light stretches. All six Teflon finished cases had light stretches (Figure 13). Of the 11 rounds fired having case Design C (six lacquer and five Teflon finished cases), four lacquer cases had light stretches and the other two were unstretched. Three of the cases with Teflon finish had obvious stretches and the remaining two were lightly stretched. Of the 12 rounds fired having case Design D (six lacquer and six Teflon finished cases), two lacquer cases and two Teflon cases had light stretches.

Visual inspection of Table 3 reveals that all 42 steel cases having case Design A and a surface finish of Mader lacquer performed satisfactorily during dry chamber tests. Three of six cases showed stretches during wet chamber tests. The next best group of cases were of the same design, but had a Teflon surface finish.

Table 3. Test summary of final case designs

Propellant load[a]	Firing rate[b]	Conditioning	Case design[c]	Finish[d]	No. tested	No. stretched	Remarks
Dry chamber tests							
Normal	Low	Ambient	A, B, C	M, D	42	0	
Normal	Low	Cold	A, B, C	M, D	42	0	
Normal	Low	Hot	A	M, D	14	0	
Normal	Low	Hot	B	M	7	2	Stretches were light.
Normal	Low	Hot	B	D	7	6	Stretches were light.
Normal	Low	Hot	C	M	7	7	Fired after cold rounds - similar to wet chamber tests; six stretches were light.
Normal	Low	Hot	C	D	7	7	Stretches were light.
Normal	High	Hot	A	M	7	0	
Normal	High	Hot	A	D	7	3	Stretches were light.
Normal	High	Hot	B	M, D	14	14	Stretches were light.
Normal	High	Hot	C	M, D	14	14	Stretches were light.
Excess	Low	Ambient	A	M, D	14	0	
Excess	Low	Ambient	B	M	3	0	
Excess	Low	Ambient	B	D	3	2	Stretches were light.
Excess	Low	Ambient	C	M	7	2	Stretches were light.
Excess	Low	Ambient	C	D	7	7	Stretches were light.

Excess	High	Ambient	A	M	7	0	
Excess	High	Ambient	A	D	7	1	Stretch was light.
Excess	High	Ambient	B	M	7	2	Stretches were light.
Excess	High	Ambient	B	D	7	6	Stretches were light.
Excess	High	Ambient	C	M	7	3	Stretches were light.
Excess	High	Ambient	C	D	7	5	Stretches were light.
Excess	Low	Ambient	D	M	7	2	Stretches were light.
Excess	Low	Ambient	D	D	7	1	Stretch was light.
Wet chamber tests							
Excess	Low	Ambient	A	M	6	3	Stretches were light.
Excess	Low	Ambient	A	D	6	5	Stretches were light.
Excess	Low	Ambient	B	M	6	6	Four obvious stretches; two light.
Excess	Low	Ambient	B	D	6	6	Stretches were light.
Excess	Low	Ambient	C	M	6	4	Stretches were light.
Excess	Low	Ambient	C	D	5	5	Three obvious stretches; two light.
Excess	Low	Ambient	D	M	6	2	Stretches were light.
Excess	Low	Ambient	D	D	6	2	Stretches were light.

[a] Normal pressure - 56,000 to 60,000 lbf/in^2; excess pressure - 67,000 to 70,000 lbf/in^2.
[b] Low rate - 2,100 SPM; high rate - 4,200 SPM.
[c] Description of all case designs contained in AFATL-TR-78-138. Design D weight - 0.45 lb.
[d] M - Mader lacquer finish; D - 30% Teflon finish.

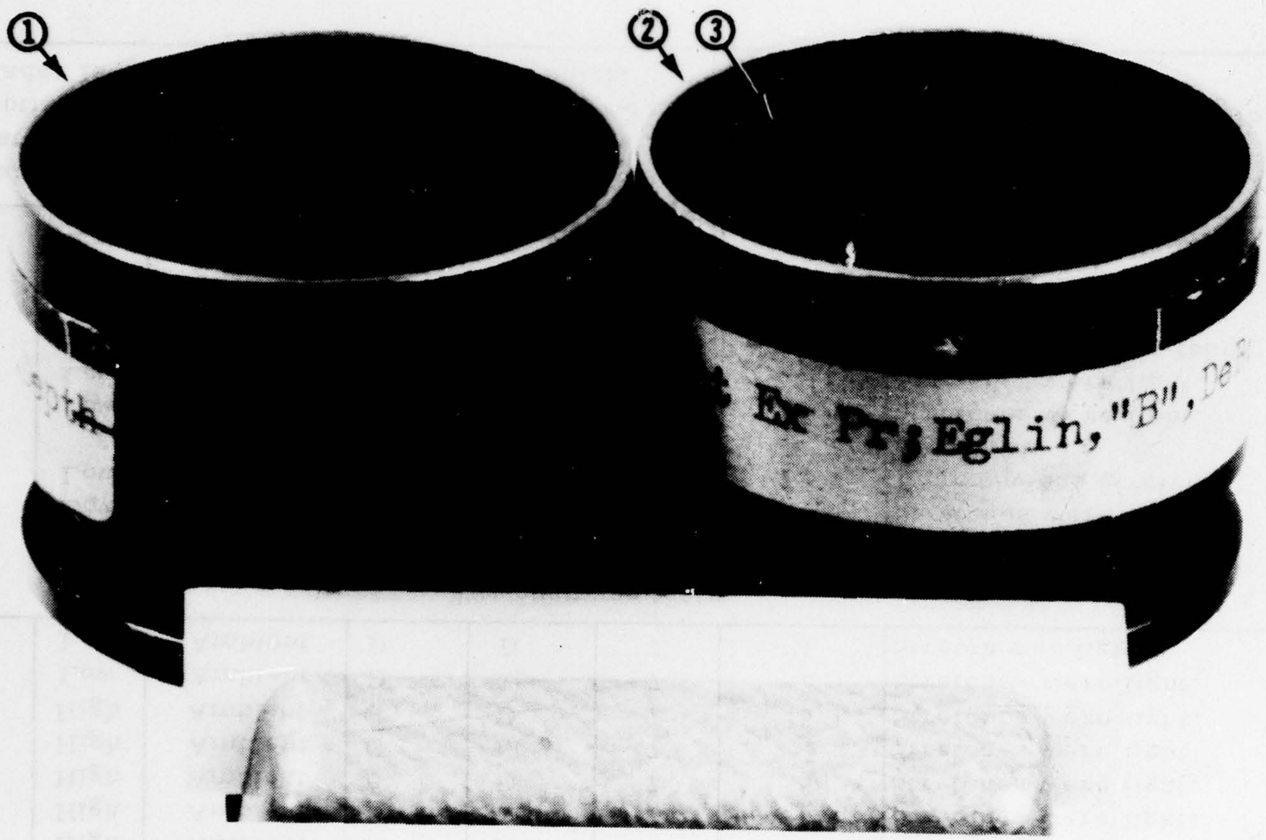

Figure 13. Two sectioned cases from Group O firing giving comparison of (1) Mader lacquer case without stretch and (2) Teflon case showing (3) stretch

SECTION VI

SUMMARY OF FINDINGS

A total of 1,041 steel case rounds were fired during this test effort. The final 305 of these rounds represent the final configurations tested and were used to answer test Objectives 3 and 4.

1. Steel case rounds were cycled in a preproduction GAU-8 gun system with no interference or compatibility problems. Handling marks on the cases were normal.

2. A total of seven steel case rounds were fired in, extracted from, and rechambered in hot barrels. Chamber temperature had no visible effect on the case finish (Group K).

3. A total of 179 steel case rounds from Group O were fired in bursts of up to seven rounds at ambient temperature. Of these, 21 rounds of case Design A having a Mader lacquer finish performed satisfactorily during tests with dry chambers. Results are tabulated in Table 3.

4. A total of 126 steel case rounds from Group O were fired in bursts of up to seven rounds after hot (160°F) and cold (-65°F) temperature conditioning. Twenty-one rounds having case Design A and a Mader lacquer finish were fired with no cracks or stretches. Results are tabulated in Table 3.

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APPENDIX

METRIC CONVERSION FACTORS

This appendix presents conversion factors to convert from units customarily used in the United States to metric units. This information was extracted from Pamphlet E380-76, American Society for Testing and Materials (ASTM), 19 January 1976, which was approved 19 January 1976 for use within the Department of Defense.

To convert from	To	Multiply by
Foot (ft)	Meter (m)	3.048 000 E-01
Pound force (lbf)	Newton (N)	4.444 222 E-00
Pound (lb)	Kilogram (kg)	4.535 924 E-01
Inch (in.)	Meter (m)	2.540 000 E-02

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314 AD/INT APO SF 96301	1
Eglin AFB FL 32542 ADTC	
DLODL	2
3201 ABG/HO	1
3246 TESTW/TEO	1
3246 TESTW/TETF	12
3246 TESTW/DLDG	15
USAFTAWC	
TXA	1
TVW	1